available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/ecolecon

ANALYSIS

Natural vs. financial insurance in the management of public-good ecosystems

Martin F. Quaas[a,*], *Stefan Baumgärtner*[b]

[a]*Department of Ecological Modelling, UFZ — Helmholtz Centre for Environmental Research, Permoser Str. 15, D-04318 Leipzig, Germany*
[b]*Centre for Sustainability Management, University of Lüneburg, Germany*

ARTICLE INFO

Article history:
Received 27 October 2006
Received in revised form
19 April 2007
Accepted 6 July 2007
Available online 29 August 2007

Keywords:
Ecosystem services
Ecosystem management
Endogenous environmental risk
Insurance
Multi-scale ecosystem functioning
Risk aversion
Uncertainty

JEL classification:
Q57; H23; D81; D62

ABSTRACT

In the face of uncertainty, ecosystems can provide natural insurance to risk averse users of ecosystem services. We employ a conceptual ecological–economic model in which ecosystem management has a private insurance value and, through ecosystem processes at higher hierarchical levels, generates a positive externality on other ecosystem users. We analyze the allocation of (endogenous) risk and ecosystem quality by risk averse ecosystem managers who have access to financial insurance, and study the implications for individually and socially optimal ecosystem management, and policy design. We show that while an improved access to financial insurance leads to lower ecosystem quality, the effect on the extent of the public-good problem and on welfare is determined by ecosystem properties. We derive conditions on ecosystem functioning under which, if financial insurance becomes more accessible, (i) the extent of optimal regulation increases or decreases; and (ii) welfare, in the absence of environmental regulation, increases or decreases.

1. Introduction

Ecosystems provide many valuable services, including goods such as food, fuel or fiber, and services such as pollination or the regulation of local climate, pests, diseases or water runoff from a watershed (Daily, 1997; Millennium Ecosystem Assessment, 2005). In a world of uncertainty, human well-being depends not only on the mean level at which such services are being provided, but on their statistical distribution. Biodiversity can reduce the variance at which desired ecosystem services are provided. This means, biodiversity can provide a natural insurance to risk averse users of ecosystem services. Since increasing biodiversity generates such an insurance value for ecosystem managers, they tend to employ more conservative management strategies in the face of uncertainty (Baumgärtner, 2007; Baumgärtner and Quaas, 2006).

On the other hand, rather than making use of natural insurance, ecosystem users can also use financial insurance to hedge their income risk. For example, in the USA for over one hundred years crop yield insurance is offered to manage agricultural risk. Since traditional crop yield insurance is particularly vulnerable to classical insurance problems such as moral hazard or adverse selection (e.g. Luo et al., 1994), considerable effort is recently spent to develop alternative

* *Corresponding author.*
E-mail address: martin.quaas@ufz.de (M.F. Quaas).

0921-8009/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2007.07.004

possibilities of financial insurance for farmers, e.g. index-based insurance contracts (Miranda and Vedenov, 2001; Skees et al., 2002; World Bank, 2004).

While this effort to develop instruments of financial insurance is motivated by the idea that reducing income risk is beneficial for ecosystem users, some studies have shown that financial insurance tends to have ecologically negative effects. Horowitz and Lichtenberg (1993) show that financially insured farmers are likely to undertake riskier production – with higher nitrogen and pesticide use – than uninsured farmers do. A similar result is pointed out in Mahul (2001), assuming a weather-based insurance. Wu (1999) empirically estimates the impact of insurance on the crop mix and its negative results on soil erosion in Nebraska (USA).

In this paper, we analyze how risk-averse ecosystem managers make use of the natural insurance function of biodiversity and of financial insurance. We address the question of how the availability of financial insurance affects the overuse of natural resources and social welfare when ecosystem management measures generate both a private benefit and, via ecosystem processes at higher hierarchical levels, positive externalities on other ecosystem users.

Our analysis of biodiversity and the provision of ecosystem services captures important insights about ecosystem functioning that emerged from recent theoretical, experimental and observational research in ecology (Hooper et al., 2005; Kinzig et al., 2002; Loreau et al., 2001, 2002; Holling, 2001; Levin, 2000; Peterson et al., 1998; Tilman, 1994; O'Neill, 1986).[1] Among other insights two 'stylized facts' about biodiversity and ecosystem functioning emerged which are of crucial importance for the issue studied here:

1. *Local biodiversity is affected by ecosystem processes at different hierarchical scales*. Ecosystems are hierarchically structured, with processes operating at different spatial and temporal scales and interacting across scales. Species diversity is typically influenced differently by processes at different scales. Accordingly, biodiversity management measures at different scales have different impact on local biodiversity.
2. *Biodiversity may reduce the variance of ecosystem services*. In many instances, an increase in the level of biodiversity monotonically decreases the temporal and spatial variability of the level at which these ecosystem services are provided under changing environmental conditions. This effect decreases in magnitude with the level of biodiversity.

These stylized ecological facts are of economic relevance.[2] Biodiversity increasing management provides users with natural insurance in terms of a reduced variance of ecosystem services. In particular, an individual manager's action affects biodiversity via ecosystem processes at different scales. At a lower scale, benefits accrue exclusively to him. At a higher scale his action can contribute to increasing local biodiversity for other users, thereby generating a positive externality. For example, by setting aside land on his farm as habitat for insects, an individual farmer increases the local level of biodiversity on his farm and also contributes – via metapopulation dynamics (Hanski, 1999; Levins, 1969) – to biodiversity on other farms.

Our analysis of environmental risk, ecosystem management and purchase of financial insurance brings together three separate strands in the literature: (i) In the environmental economics literature, Crocker and Shogren (1999, 2001, 2003) and Shogren and Crocker (1999) have developed the idea that environmental risk is endogenous, that is, economic decision makers bearing environmental risk may influence their risk through their actions. They have formalized decision making under uncertainty in this context by conceptualizing ecosystems as lotteries. (ii) In the literature on the use (or provision) of a public good under uncertainty, the conventional wisdom seems to be that the higher the uncertainty or the risk aversion of individual decision makers, the less severe is the problem of overuse (or under-provision) of the public good (Bramoullé and Treich, 2005; Sandler and Sterbenz, 1990; Sandler et al., 1987). The focus in this literature is on the properties of the utility function, while the production of the public good (or public bad) is typically modeled in a trivial way, i.e. one unit of money spent on providing the public good equals one unit of the public good provided. (iii) In the insurance economics literature, the analysis of the trade-off between 'self insurance' (by acting such as to reduce a potential income loss) or 'self protection' (by acting such as to reduce the probability of an income loss) on the one hand, and 'market insurance' on the other hand goes back to Ehrlich and Becker (1972). One standard result is that self insurance and market insurance are substitutes, with the result that market insurance, as it becomes cheaper, may drive out self insurance. In this paper, we bring together these three lines of argument.

We study a conceptual ecological–economic model of agro-ecosystem management where the direct economic use of some ecosystem service (e.g. crop yield) relies on other ecosystem services (e.g. pollination or pest control) from natural or semi-natural ecosystems. The directly used ecosystem service (crop yield) is random because of exogenous sources of risk (e.g. weather conditions or pests outbreaks); its distribution (mean and variance) is determined by ecosystem quality (biodiversity). Ecosystem quality, in turn, can be influenced by management action (e.g. setting aside land as habitat to enhance biodiversity) that affects ecosystem processes at different scales (e.g. farm scale and landscape scale).

A typical example of such a system is a highland coffee plantation. Fruit set of coffee plants (*coffea arabica*) is highly variable and related to bee pollination. Ecological evidence shows that the variability of coffee fruit set decreases with on-plantation bee diversity (Klein et al., 2003a,b). Arthropods and leaf damage are controlled by insectivory birds (Greenberg et al., 2000; Kellermann et al., 2006). Both types of species (bees and birds) rely on rainforest as habitat, but their activity range is at different spatial scales: while (social) bees visit coffee plants at a distance of 1.5 km and less (Klein et al., 2003a,b), birds easily visit also neighboring plantations, even if there

[1] The article by Hooper et al. (2005) is a committee report commissioned by the Governing Board of the Ecological Society of America. Some of its authors have previously been on opposite sides of the debate. This report surveys the relevant literature, identifies a consensus of current knowledge as well as open questions, and can be taken to represent the best currently available ecological knowledge about biodiversity and ecosystem functioning.

[2] For a more detailed and encompassing discussion of these findings, and references to the literature, see Baumgärtner (2007), Baumgärtner and Quaas (2006) and Hooper et al. (2005).